



United States General Accounting Office

Report to the Chairman, Subcommittee
on Military Research and Development,
Committee on National Security, House
of Representatives

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NAVY SHIP PROPULSION

Viability of New Engine Program in Question



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National Security and
International Affairs Division

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The Honorable Curt Weldon
Chairman, Subcommittee on Military
Research and Development
Committee on National Security
House of Representatives

Dear Mr. Chairman:

In response to your request, we are providing this report, which discusses the Department of the Navy's development of a new ship propulsion system, the intercooled recuperated (ICR) gas turbine engine. Our review focused on the (1) Navy's need for the engine; (2) cost, schedule, and performance of the engine testing program; and (3) impact of the test results and funding issues on the program's test and development strategies.

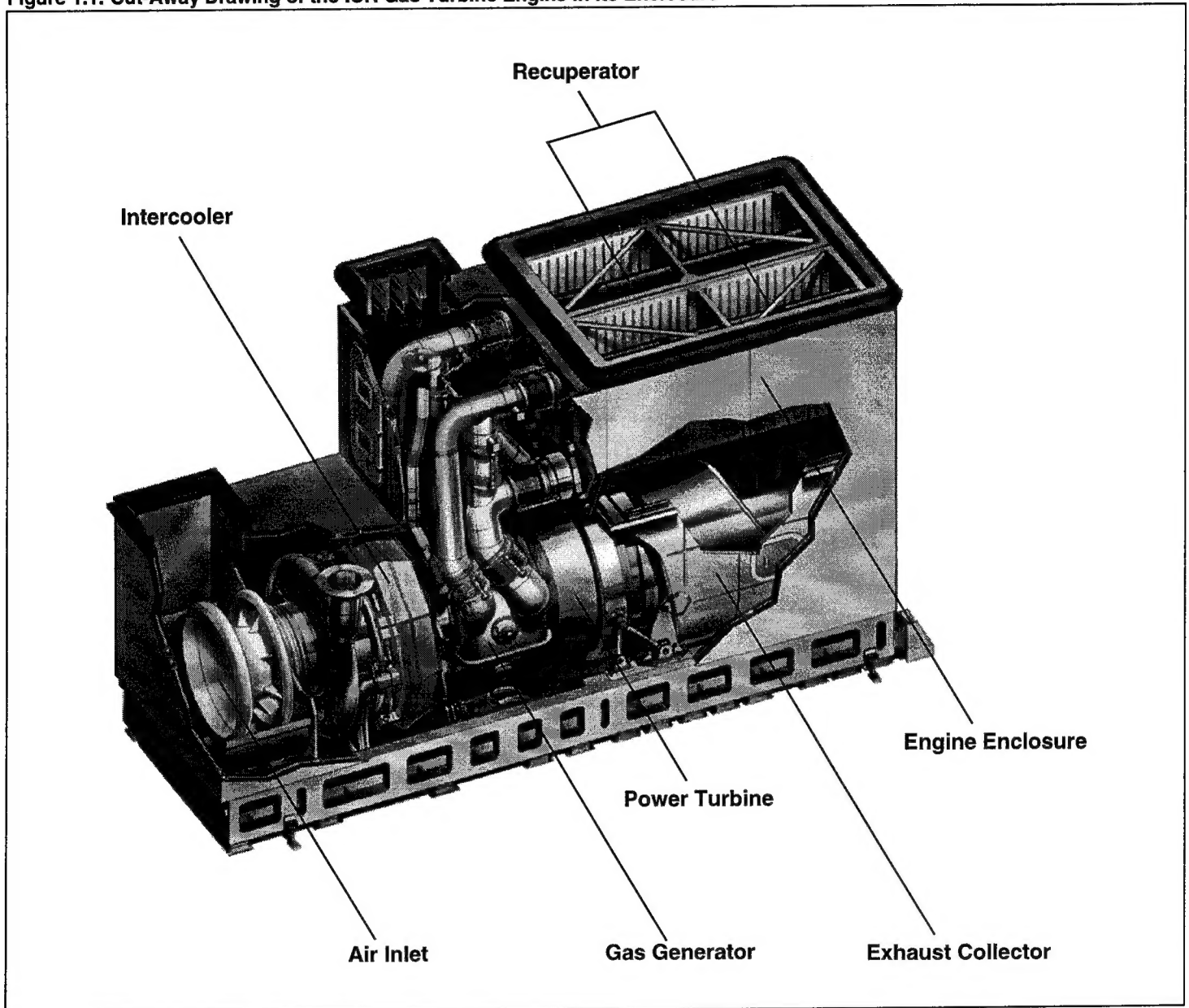
Background

The ICR gas turbine engine program was established in the mid-1980s to develop an improved surface ship propulsion system that would be fuel efficient. In December 1991, the Navy awarded a contract to the Westinghouse Electric Corporation for the advanced design and an option for full-scale development of the engine.¹ Their engine development team includes Rolls-Royce Public Limited Company (United Kingdom), AlliedSignal Aerospace Incorporated, and CAE Electronics.

The engine is essentially an advanced gas turbine engine, similar to the one used on a large commercial aircraft. It is being adapted for marine use by adding a recuperator, an intercooler, and other major components. Housed in a special enclosure, the engine also has a lube oil module, an off-engine intercooling module, and a digital control system specifically built for shipboard application. A critical component of the engine is the recuperator. The recuperator uses engine exhaust to preheat compressed air before fuel combustion, allowing the engine to use less fuel. For example, the Navy expects the ICR engine to achieve a weighted average improvement of 30 percent in fuel efficiency for a mechanical drive destroyer. Figure 1.1 shows a cut-away drawing of the ICR gas turbine engine in its planned enclosure.

¹In January 1996, the Westinghouse Electric Corporation division responsible for the ICR engine was sold to the Northrop Grumman Corporation.

Figure 1.1: Cut-Away Drawing of the ICR Gas Turbine Engine in Its Enclosure



Source: Westinghouse Electric Corporation.

Portions of the ICR program are a collaborative effort among the United States, British, and French navies. Memorandums of understanding, signed between the United States and the two other countries, relate to the development of an advanced, fuel efficient ship propulsion system to satisfy common operational requirements and meet emerging environmental emission standards. The memorandum of understanding with the United Kingdom calls for the joint development and qualification testing of the ICR engine. Specifically, the United Kingdom is responsible for providing an ICR test facility along with fuel, utilities, and manpower to support up to 2 years, or 1,500 hours, of developmental testing. The memorandum was signed on June 21, 1994, for a 5-year period. The 10-year memorandum signed by France, in August 1995, calls for the joint adaptation and testing of an ICR engine upgrade for reducing exhaust emissions.

The U.S. Navy estimates the ICR program's developmental total cost² to be \$415 million, with \$223.6 million having been spent through fiscal year 1995. These amounts include foreign financial contributions of \$15.8 million from the United Kingdom and \$15 million from France. Although the Navy has classified the engine as a preplanned product improvement program³ for the DDG-51 destroyer, it will not decide on whether it will install the ICR engine on the destroyer until January 1997. The British and French navies are completing the design of a multinational frigate, known as the Horizon, and are considering the engine as its propulsion system. The only operational ICR test facility established, to date, is at Pyestock, United Kingdom.

Results in Brief

After more than 4 years of advanced development, some Navy officials are questioning whether the ICR engine will provide a viable and timely return for the large investment needed to develop it. One high level Navy official has recommended that the engine not be funded in the future because it does not provide a reasonable prognosis for long-term benefit, while another has stated that the program has marginal merit in light of other priorities. A Center for Naval Analyses report notes that the engine's development costs are significant, questions the affordability of the

²Total developmental program cost assumes exercising all contract options, which includes five ICR gas turbine engines, development test, U.S. Navy qualification and shock tests, and ship integration testing.

³A preplanned product improvement for an ongoing system is defined as an improvement that goes beyond current system performance to achieve needed operational capability.

engine, and concludes that the economic payoff for the engine is so long term that it might not be an attractive investment.

Although the ICR program is designated a preplanned product improvement for the DDG-51 destroyer program, several Navy officials (including officials from that program office) have raised concerns about the practicality of placing the engine on the destroyer since it is already equipped with a capable and reliable propulsion system. The Center for Naval Analyses, in a 1994 cost-benefit analysis, concluded that the engine should not be used on the destroyer due to the high cost involved. Given the (1) small number of new U.S. destroyers involved, (2) adequacy of the current destroyer engine, (3) high cost and difficulty of incorporating the engine into the destroyer, (4) uncertain status of DDG-51 integration plans, and (5) current state of ICR development, we believe the Navy should at least wait for a more appropriate new ship for the ICR engine.

The Navy is experiencing serious problems in the development and testing of the ICR engine's recuperator and has yet to recover from a January 1995 recuperator failure that resulted from design, manufacturing, and quality assurance problems. As of April 1996, a modified recuperator had operated for only about 120 hours. This, along with earlier testing, is approximately 9 percent of the 1,500 hours the Navy had hoped to achieve under the memorandum of understanding with the United Kingdom. While the contractor has instituted a Navy-approved recovery plan to redesign future recuperators, the plan did not provide sufficient time to evaluate test data prior to key redesign activities. This was due to a need to meet a planned, late 1996 decision date to order production ICR engines for the international Horizon frigate.

In November 1995, the Navy halted work on redesigning future recuperators because of funding reductions, contractor quality control problems, manufacturing problems, and delivery delays.⁴ The Navy is working with the primary contractor to resolve these problems, in part, by restructuring the ICR program. For example, officials are considering reducing contractual requirements, such as the number of preproduction engines purchased, and rescheduling program milestones. These programmatic changes can be expected to reduce the scope of the developmental program and to cause testing delays and cost growth. The possibility of cost growth also raises questions about the viability of the Navy's estimate of \$415 million to develop the ICR engine. For example, the

⁴As of May 21, 1996, the stop work order was still in effect.

Navy has not yet adjusted program cost estimates to reflect schedule slippage and technical difficulties.

As the Navy restructures the ICR engine's development program, it faces two major decisions concerning the test program's infrastructure. The first decision is how and if it will use a \$5.4 million ICR test facility that it built in Philadelphia. Currently, the Navy plans to conduct almost all of its ICR engine developmental testing at the test site in the United Kingdom. The second is whether it will test the ICR engine at sea in a pilot ship. The cost to test the engine at sea is estimated to range from \$5.8 million to \$12.5 million.

The Value of and Need for This Program Are Being Questioned

In a September 1995 letter to the Navy's Deputy Chief of Naval Operations (Resources, Warfare Requirements and Assessments), the Navy's Commander in Chief, Atlantic Fleet, recommended that the ICR engine not be funded in the future, noting that "in this year's . . . budget process, the ICR Gas Turbine Engine Program stands out as a major cost without a realistic prognosis for long-term benefit." He stated that the engine's long-term cost-benefit projections are speculative at best and that its technology will most likely become obsolete before a return on its investment is realized. He also stated that the engine is not a viable candidate for existing ships due to its large size, weight, and cost. In an October 1995 reply, the Deputy Chief of Naval Operations stated that the Navy may decide the fate of the engine program as it finalizes its budget submission for fiscal year 1998.

In November 1995, a high level Navy official informed us that the Navy's need for the engine was marginal compared to other current priorities and that he believed the Center for Naval Analyses' ICR report does not make a compelling economic case for the continued development of the engine. However, he also noted that the Department of Defense (DOD) supported the international aspects of the program and that the results of the upcoming developmental testing will be critical to determining the program's future.

Center for Naval Analyses Study Raises Affordability and Other Concerns

In a September 1994 cost-benefit analysis for the Assistant Secretary of the Navy (Research, Development and Acquisition), the Center for Naval Analyses looked at the ICR engine and an improved version of the current DDG-51 engine. The report, which was prepared prior to the initial test of the engine and recuperator, states that "(t)he economic payoff for a

fuel-efficient engine is so long-term that it might not be an attractive investment in the private sector, but the eventual benefits of either improved engine are not in doubt, only the near-term affordability.” The analysis stated that the Navy’s 1993 ship building plans for gas turbine surface ships are less than half what they were expected to be in 1987 and that such a large reduction could call into question the idea of a costly ICR engine development paid for by fuel savings. Further, the remaining development costs for the engine were significant. It would take until at least 2026 for the cost savings from the engine to equal the Navy’s investment, and the Navy needed to determine what priority it should give to the engine’s development. The analysis concluded that while existing contractual and political obligations would make cancellation of the engine an unpleasant choice, the high cost to develop the engine—estimated to be an average of \$40 million per year through fiscal year 1999—means that program cancellation must be considered an option. In a December 1994 letter to the Chairman of the House Committee on Armed Services, the Secretary of the Navy stated that the report’s analysis supported the continued development of the ICR engine because of potential future fuel savings.

Engine’s Use in Navy Destroyer Is Questionable

According to the Navy, the ICR engine is expected to provide military advantages, such as increased range and time on station for the DDG-51, which the Navy considers desirable and which formed the basis for DOD’s approving the engine as a preplanned product improvement for the DDG-51. However, Navy officials have raised concerns about the viability of placing the engine on the DDG-51. Officials from the DDG-51 program office stated that the destroyer is currently equipped with a reliable gas turbine engine and that equipping it with the unproven ICR engine is a questionable decision.⁵ They noted that the Navy’s next generation surface combatant, planned for 2003, appeared to be a better candidate for the engine because it could be designed from the start to accept the engine. An ICR program official also called the ICR engine’s use on the DDG-51 questionable but noted that this decision gives the Navy an immediate need for the engine. He agreed that the Navy’s next generation surface combatant would be a better candidate since it could be designed to accept a new propulsion system.

⁵In June 1994, a DOD information paper on the ICR engine noted that acquisition and installation costs related to putting 26 ICR engines in the last 13 destroyers to be built would be \$249.3 million, in then-year dollars. Further, the cost of acquiring and installing two ICR engines in a DDG-51 was estimated to be \$13.5 million, in then-year dollars, more per ship than two of the current engines.

In 1992, we reported that the ICR program lacked adequate management controls, such as milestone reviews and comprehensive, independent cost estimates.⁶ In February 1994, the Under Secretary of Defense designated the ICR engine program as a preplanned product improvement for the DDG-51 destroyer in an effort to improve its management and ensure that it was subject to the approval of the Defense Acquisition Board and an independent cost estimate. The decision, however, on whether to actually use the ICR engine on the DDG-51 will not take place until January 1997. In addition, the first production engines would not be installed in a DDG-51 until over 7 years later, in 2004. The initial engine is expected to be ordered in 2001. If the engine is used on the DDG-51, the Navy now plans to put it on only the last nine destroyers to be built.

The Center for Naval Analyses cost-benefit analysis of the ICR engine concluded that the engine should not be used on the DDG-51 due to the high cost to fit the engines on ships that were not designed for them and the small number of destroyers (14 at that time) remaining to be built. The analysis also noted that the projected break-even point between the cost savings generated by the engine and the Navy's investment, based on 79 possible candidate ships (including the DDG-51 destroyers), would not occur until about 2026. If the engine is not put on the DDG-51, as the analysis recommends, then the number of identified candidate ships would be reduced to 65. In either case, the analysis noted that the cost of replacing the DDG-51 engine is significant. The analysis estimates that the cost to equip a new DDG-51 with two ICR engines is \$12.4 million (in fiscal year 1994 dollars) more than the current engines. This increase in cost includes design, shipbuilding, and engine costs. This cost compares with the \$4.9 million cost increase estimate for the other gas turbine engine in this study (a more fuel-efficient version of the current engine). The analysis suggests that the Navy confirm this estimate before acting on its recommendation.

The Westinghouse contract requires the development of an ICR engine that will occupy the same space as the existing engine in the DDG-51. Current plans call for each new destroyer to be equipped with two ICR engines and two existing gas turbine engines. These plans present design and integration problems for the DDG-51 because the ship's engine compartment will need to be redesigned to accommodate the larger ICR engine. Since the ICR engine module is expected to weigh two and one-half times more than the existing engine system, the engine compartment will

⁶1993 Navy Budget: Potential Reductions and Rescissions in RDT&E Programs (GAO/NSIAD-92-322BR, Sept. 29, 1992).

require substantial modification to achieve the structural strength needed to support the added weight of the engine. In addition, with two different propulsion systems on each ship, the Navy will have to maintain individual logistics for each system.

In March 1995, two shipyards building the DDG-51, Ingalls Shipbuilding Incorporated and Bath Iron Works Corporation, submitted reports to the Navy concerning the feasibility of installing an ICR engine in the DDG-51. Ingalls reported that while the installation was technically feasible, maintaining the ICR engine would be difficult because it has about 30 percent more preventive maintenance requirements than the current engine. Also, Ingalls reported "unlike the (current engine), most in-place maintenance activities will not be convenient or expeditious due to the very limited access to the ICR engine components." Bath Iron Works concluded that replacing two of the present propulsion gas turbines with ICR gas turbines would have a significant negative impact on the ship and a clear potential for cost growth.

Serious Problems Experienced in Developing and Testing the Engine's Recuperator

The ICR engine's recuperator, a critical component necessary for obtaining improved fuel economy, is experiencing serious developmental and testing problems. It failed after only 17 hours of testing with the engine in January 1995. The failure occurred almost 1-1/2 years after the Navy took the unusual step of initiating full-scale development of the engine concurrently with its advanced development. Since the failure, the ICR program has experienced technical and other problems that have severely affected program cost, schedule, and performance.

Recuperator Failure Forces Major Program Restructuring

The engine, without a recuperator, started developmental testing in July 1994. In December 1994, when the Navy first tested the engine with a recuperator, the engine demonstrated its potential effectiveness by increasing engine power from 7,000 horse power to 11,500 horse power with no increase in fuel consumption. In January 1995, however, the original recuperator failed after only 17 of 500 hours of planned testing. Test operations were terminated when a significant rise in the turbine inlet temperature occurred. This rise in temperature was attributed to the failure of the heat exchanger, within the recuperator, due to numerous air leaks.

Westinghouse, the primary contractor, identified 26 different recuperator failures, many of which were due to basic flaws in the unit's internal

design and construction. In response, the Navy approved a contractor recovery plan to redesign the recuperator and requested an additional \$11 million from Congress to fund this effort.⁷ As a result, the Navy extended the advanced development phase of the contract by 21 months, until September 1997. The plan allowed, however, key recuperator tests to be conducted concurrently with the redesign of the recuperator. One program official described the plan as aggressive while another told us that this was necessary to accomplish enough testing (such as a key 500-hour engine test) to support a planned late 1996 decision to order production engines for the Horizon frigate.⁸

Between March and November 1995, the Navy reduced projected program funding by \$27.3 million between fiscal years 1996 and 2000. In November 1995, the Navy also ordered Westinghouse to stop work on designing and manufacturing later generation recuperators. The stop order was issued due to the decline in program funding and the inability of the contractor to meet the delivery date for the modified recuperator. This latter problem was due, in part, to continuing contractor quality control problems. According to the Navy, the stop work order reduced the amount of concurrency in the recuperator recovery program by allowing time to review and incorporate various test results into thermal computer models and evaluate test results from the modified recuperator. The Navy also requested that the contractor propose possible changes to current contract requirements, including revising the schedule, estimating cost by quarter, and eliminating test efforts related to integration of the ICR engine into the DDG-51.

In response to the funding reduction and the stop work order, Westinghouse notified the Navy that while the technical problems associated with the recuperator were understood and solutions were in place, the engine's development would be delayed an additional 20 months, until May 1999. In addition, Westinghouse recommended, among other things, that the number of preproduction engines used for developmental testing be reduced from five to two. Westinghouse also stated that cost growth has occurred and identified potential future development and production cost risks. Westinghouse agreed to provide the Navy an overall recuperator recovery strategy by May 1996.

⁷The ICR program office estimates the cost of the recuperator recovery program to be \$25 million. However, since the Navy has not completed restructuring and rebaselining the program, this estimate cannot be verified.

⁸On March 1, 1996, we were informed that the decision to put the ICR engine on the Horizon had been delayed until the summer of 1997. The first Horizon is expected to be operational in 2002.

In March 1996, an ICR program official told us that the impact of the initial recuperator failure on the ICR program has been catastrophic and that the Navy has yet to recover from it. The Navy expects that the developmental program's scope will be reduced, resulting in testing delays and cost growth. Navy and DOD officials told us, in commenting on our draft report, that while they believe significant progress has been achieved in solving the problems associated with the recuperator failure, the ICR development program will not recover its schedule slippage and that a technical recovery is only possible.

Uncertainty of Cost Growth Raises Questions About the Program's Viability

In our September 1992 report, we stated that "without reliable estimates of both (1) the cost of acquiring the ICR engine and related technology and (2) the corresponding savings in operational cost that it might produce, it is our view that any return on the sizeable investment this program represents is speculative at best." Our view remains unchanged because of concerns about the realism of the ICR engine's development schedule and concurrency in the recovery plan test schedule; recognized difficulties in integrating the engine into DDG-51 fleet; the overall high cost of the program; and total program costs that are not fully covered in existing budget plans.

Specifically, the Navy has not funded the cost to finalize and perform ICR developmental testing at an established U.S. facility (\$17 million), to integrate an ICR engine into the DDG-51, or to retrofit a pilot ship for testing at sea. In addition, to keep total program costs at \$415 million, the Navy plans to reduce the scope of its developmental test efforts and use funds intended for other test purposes to offset the expected \$25 million recuperator recovery program cost.

Also, in May 1994, the ICR engine contract was modified by deleting special tooling and special test equipment costs since the contractor agreed to fund these costs, if Navy funds were not available. The contractor is to maintain a separate account of these costs for future recovery. Future payment for such tools and equipment will obviously increase total program costs.

Plans for the Horizon Frigate Drove ICR Engine Schedule

A major factor that drove the ICR engine's development schedule has been the need to decide, by late 1996, whether the engine will be used in the international Horizon frigate. The 1994 memorandum of understanding with the United Kingdom states that its goal was to move a critical ICR

engine preproduction decision milestone to mid-1996, in order to advance the initial operating capability date for both the DDG-51 and the Horizon frigate. A Navy program official acknowledged that meeting that date was part of the reason the Navy approved an aggressive recuperator recovery plan, which included redesign of the recuperator before receiving the results of key tests.

During 1995, the House Committee on Appropriations recommended, in its report on the fiscal year 1996 DOD appropriations bill, that the program be terminated because of concerns about serious technical problems, high unit cost, and program cost-effectiveness. In a July 13, 1995, letter to the Chairman of the House Appropriations Committee, the British Ambassador expressed his concern about funding for the ICR engine program. He stated that the United Kingdom plans to use the engine for its next generation of warships. He noted, however, that if U.S. funding for the ICR program was eliminated by Congress it would be incomprehensible to the British government and it could help encourage a movement toward a protectionist European defense market. In an August 28, 1995, letter to the same Chairman, the Secretary of Defense also expressed concern over the possibility that all ICR program funds would be deleted and that the program would be terminated in the House appropriations bill. Noting that the ICR engine is a candidate for all future nonnuclear Navy surface ships, he stated that the United Kingdom and France are committed to fielding the engine on their next generation of surface combatant ships and that termination of the program would be a potential embarrassment for the U.S. government. Full funding was restored to the program as a result of the conference committee meeting between the Senate and House. An additional \$15.4 million, primarily for the recuperator recovery program, was also appropriated.

Necessary Test Data Will Not Be Fully Available

Despite some progress made in improving the recuperator recovery plan, the test data necessary for decision making will still be limited. The original recuperator recovery plan recommended that a test unit and three additional generations of recuperators be manufactured during the developmental effort. Each would be designed with a longer service life than the previous one and would provide different solutions to address the failures. However, much of the testing of one generation would be conducted concurrently with the redesign of the next generation recuperator, thus severely limiting the contractor's ability to improve the redesign based on test results. For example, a series of recuperator core component tests (there are eight of these heat exchanging cores in a

recuperator) were scheduled simultaneously with the redesign of the next recuperator.

To support the redesign efforts, a series of component tests are planned with a full-sized recuperator core. Such component testing had not been performed on the original recuperator due to the manufacturer's attempt to meet delivery schedules for developmental testing. The manufacturer was behind due to (1) delays in awarding the subcontract to AlliedSignal, (2) refurbishing of the brazing furnace to satisfy safety requirements, and (3) manufacturing additional core units to replace poorly manufactured component units. The recovery plan concluded that these component tests "are crucial to support the design evolution of the core configuration and are more effective and provide earlier test data." Due to delays in receiving these core component test results, which are necessary to validate model predictions, the Navy directed the contractor to stop testing the modified recuperator in January 1996. This action was necessary since the contractor had failed to provide substantiating data from the core tests to allow certain engine test maneuvers. Furthermore, in later correspondence, the Navy denied a particular test maneuver since the Navy believed the contractor's proposed approach was inconsistent with the long-range requirement of extending the modified recuperator's useful life for future testing. Within a week of being told to stop testing, the contractor resumed engine testing with the modified recuperator.

A blue ribbon panel that reviewed the recovery plan determined that available test results were inadequate to predict future problem areas and the recuperator's operational life and to validate performance models. Since the recuperator's failure, the engine manufacturer has been testing the engine without a recuperator, further limiting the amount of available test data and the contractor's ability to validate performance models and engine performance.

According to Navy officials and documents, the need to have a propulsion system available for ships in development, especially the new multinational frigate, drove an aggressive recuperator recovery plan to redesign recuperators without the benefit of results from tests of individual cores and the environmental test data from a special test unit. Examination of the failed recuperator and additional materials test results, however, contributed to the design effort. The special test unit, which was created using six cores from the failed recuperator and two unused cores that had been set aside due to questionable manufacturing quality, replaced the failed recuperator. The test objectives of the special unit

included the provision of data for refining, developing, and validating analytical computer models. Modeling new design concepts is a key factor in any developmental effort. The special unit operated for about 6 hours and demonstrated that the recuperator could be operated safely by gradually increasing engine power to obtain idle speed and having the recuperator partially active. The unit was extensively instrumented to gain detailed information about the operational environment.

One of the recuperator recovery plan's objectives was to deliver a redesigned recuperator to the Pyestock test facility by October 31, 1995, but an additional schedule slippage delayed delivery until December 1995. The slippage, however, enabled the Navy to obtain some additional preliminary core component test results that were used to establish boundaries as to what test operations will be performed. For example, the engine could not initially exceed 40 percent of full power nor could the contractor restart a hot engine without risking damage to the recuperator.

Issues Concerning the Test Program's Infrastructure

As the Navy restructures the ICR engine's development program, it faces two major decisions concerning the test program's infrastructure. The first decision is how and if it will use an ICR test facility already built, but not operational, in Philadelphia. Prior to the recuperator failure, the Navy had hoped to advance significantly the development of the ICR engine by conducting joint testing in the United Kingdom and the United States. The second decision is whether it will test the ICR engine at sea in a pilot ship. Because of recuperator technical problems, funding reductions, and schedule delays, the Navy will not be able to accelerate engine development via planned joint land-based testing. Currently, the Navy plans to conduct almost all of its ICR engine developmental testing at the test site in the United Kingdom. In addition, it has yet to resolve questions related to the need to test the engine at sea.

Land-Based Testing Crucial to Advancing the Engine's Development Schedule

The Navy signed an advanced development phase contract with Westinghouse in 1991. In developing an ICR test facility, Westinghouse considered three potential test sites and selected Pyestock, United Kingdom, as its primary test site. The subsequent memorandum of understanding with the United Kingdom provided for the United Kingdom to fund the operation of the test site for up to 2 years or 1,500 hours of testing. This in-country support was estimated to total \$22 million in then-year U.S. dollars. The test facility in Pyestock began testing the ICR engine (without a recuperator) in July 1994.

When the Navy advanced the ICR engine's development schedule in 1993 by 21 months, it created a need for another ICR land test site. Both the Navy and Westinghouse believed that with two operational facilities they could conduct almost simultaneous engine tests in support of the faster development schedule. Based on the memorandum of understanding with the United Kingdom, the United States would be responsible for funding the Philadelphia test site. This test site would also perform required technical and operational testing for the U.S. Navy.

U.S. Test Site Built but Not Operational

While the Philadelphia test facility was completed in fiscal year 1995, it is not yet operational. This is due, in part, to funding reductions and recuperator technical problems that have resulted in major delays in the developmental testing of the engine. As a result, there is currently no ICR engine and recuperator available for testing at Philadelphia. In addition, the Navy has not provided adequate funding for the operation of the Philadelphia facility in support of desired joint developmental and qualification engine testing. Complicating the situation is the fact that the recuperator failure and the subsequent 41-month delay in the development program have eliminated one of the primary justifications—to speed up the engine's development—for two land-based test facilities. The Navy now plans for almost all developmental and qualification testing to be conducted in Pyestock and, at the present time, use the Philadelphia facility near the end of the program only for ICR engine shock testing.

The Navy and Westinghouse had originally expected that the Philadelphia test facility would allow a second 500-hour developmental test after a similar test had been performed at Pyestock. By conducting these tests almost simultaneously, the Navy believed it could complete the engine's development 21 months early. The Philadelphia facility cost \$5.4 million to construct. The Navy estimates the cost to fully equip and staff the Philadelphia test facility for a 500-hour test to be \$17 million: \$9 million in fiscal year 1996 and \$8 million in fiscal year 1997. In the fiscal year 1996 budget, however, the Navy only received \$4.5 million for this test. Navy officials told us that they would not partially fund this test and that the \$4.5 million is currently being withheld by the Navy and may, sometime in the future, be rescinded.

The Navy also had planned to conduct ICR related testing at another test facility in Philadelphia. Using the DDG-51 test facility, which is built and operating, the Navy was going to accomplish tests required for integrating the ICR engine into that class of ship. Because of funding reductions and

other problems, the Navy is considering eliminating this testing. Also, the ICR test facility was to have been used to test other future ship propulsion and power projects. If the facility is not made operational, this will not be possible. Thus, the Navy currently has an ICR test facility without operational capability and an ICR engine test strategy that is in a state of limbo.

Navy Undecided If It Will Test the Engine at Sea

The Navy has not decided if it will test the ICR at sea because of the high cost involved. It estimates that it would cost between \$5.8 million to \$12.5 million to redesign a ship's engine room and install an engine in a pilot ship. While no decision has been made, this is an important testing issue. A DDG-51 program official stated that it is Navy policy to test engines at sea. A Navy testing official stated that a land-based test facility, by itself, is not adequate to fully evaluate the engine's operational effectiveness and suitability because the facility does not represent a realistic ship and maritime environment. This is, in part, because the engine compartments on surface combatants are very limited in space compared to other surface ships (e.g., cargo ships), thereby presenting more challenges for repairing or maintaining the engine. Also, the Navy has not decided what type of pilot ship the engine will be tested on. A Navy official stated that the type of pilot ship selected is important due to the various electronic support equipment associated with the engine.

Recommendations

This report raises many questions about the viability of the ICR engine program, and we believe DOD needs to reassess the need for and future direction of the program. Because the United States has entered into joint agreements with the British and French navies to develop this engine, the decisions on the future of the program are complicated and sensitive. We also believe that the use of the engine on the DDG-51 destroyer is inappropriate. Therefore, we recommend that the Secretary of Defense reassess the Navy's continuing need for the new engine. In doing so, the Secretary needs to carefully consider how current agreements with U.S. allies affect the program, identify what effect the Navy's ongoing efforts to restructure and rebaseline the ICR program will have, and determine what the Navy's surface combatant ship future requirements actually are. If it is determined that the program should continue, the Secretary of Defense should direct the Secretary of the Navy to

- not use the engine in the DDG-51 destroyer;

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- determine total program costs for developing and acquiring the engine relative to the Navy's requirements for future surface combatant ships, including costs for U.S. test facilities and/or pilot ship engine testing;
 - prepare a facility use plan for the U.S. test site; and
 - prepare a test plan and schedule for the engine that provide sufficient assurance that it can transition from development to production and be realistically available for use in any U.S. ship.
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Agency Comments and Our Evaluation

DOD said that it disagreed with our report, in large part, because the Secretary of Defense is satisfied with the Center for Naval Analyses' assessment and does not need to reassess the program at this time, as we have recommended. However, DOD's comments do not address the difficulties the program has encountered since the Center's 1994 assessment. Specifically, with the January 1995 failure of the engine's recuperator, the program has experienced serious design, manufacturing, and quality assurance problems. In response, the Navy instituted an aggressive recuperator recovery plan to maintain as much of the engine's accelerated development schedule as possible. Only in November 1995, however, did the Navy realize that this approach would not work and ordered work stopped on redesigning the recuperator. An ICR program official has described the impact of the recuperator failure on the program as being catastrophic and, as of May 21, 1996, the stop work order was still in effect.

DOD also disagreed with our recommendation to not use the engine in the DDG-51 destroyer. DOD commented that the ICR engine was expected to provide military advantages to the DDG-51, such as increased range and time on station. While acknowledging that weight and size relative to the size of the DDG-51 engine room are important, DOD commented that it is technically feasible to put the engine on the ship. DOD did not comment, however, on our concerns about the high cost of putting the engine on the DDG-51. We would like to reiterate that the Center's assessment recommended that the ICR engine not be used in the DDG-51 because of the high cost to fit these engines in a ship that was not designed for them. Moreover, representatives from the DDG-51 program office, and even the ICR program office, have said that this is an inappropriate ship for the ICR engine.

DOD commented that studies done by Ingalls Shipbuilding demonstrate that putting the ICR engine on the destroyer is technically feasible. However, DOD's comments fail to note that Bath Iron Works concluded that the

engine would have a significant negative impact on the ship and a clear potential for cost growth. Further, weight is clearly an issue when DOD tells us, in its technical comments, that the Navy will, if necessary, reduce the amount of fuel carried on the destroyer to counter the increased weight of the engine.

Concerning our recommendation to determine total program costs for developing and acquiring the engine, DOD stated that total program costs have been estimated and the ICR engine should break even around about 2020. However, when we attempted to follow up on this statement, we learned that, as of April 1996, the Navy had yet to restructure and rebaseline the program. The Navy is in the process of restructuring the program to absorb the estimated \$25 million cost to implement the recuperator recovery plan and expected reductions in out-year program funding. To accomplish this, the Navy is considering, among other things, reducing the number of preproduction engines, under the contract, from five to two. In addition, the Navy has not fully funded all of the test activities, including the U.S. land-based test facility and a pilot ship to test the engine at sea. It may even eliminate the planned DDG-51 integration testing. Thus, total program costs are not fully known and we are concerned about what test activities the Navy plans to reduce or eliminate to keep total program costs down.

In addition, the Center for Naval Analyses actually predicts the break-even point, when savings would equal the development cost, as being in 2026, not 2020 (based on the first engines being installed in a fiscal year 1999 DDG-51). Under current Navy plans, however, ICR engines would not be installed until 2004, meaning that the break-even point is likely to occur even later than 2026.

Concerning our recommendation to prepare a test plan and schedule that provides sufficient assurance that the engine can transition from development to production and be realistically available for future use, DOD stated that if the decision was made to use the ICR engine on a particular ship, test planning and scheduling would be incorporated into that ship's test and evaluation master plan. However, with the decision to put the engine on the DDG-51 at least a half year away and a stop work order still in effect, we are more concerned about the current test plan and schedule for the engine's development. Until the Navy restructures and rebaselines the program we will be unable to determine if test concurrency has been eliminated and if adequate time has been provided for developmental testing and the evaluation of test results. DOD also

pointed out that the United States has no cognizance over the Horizon program and that the United Kingdom, France, and Italy would develop their own test plans. We have revised our recommendation to specify that it only applies to U.S. ship development.

After carefully reviewing all of DOD's comments, we continue to believe that the Secretary of Defense needs to reassess the ICR engine program and the Navy needs to resolve problems with the ICR engine's recuperator and sufficiently test the engine prior to committing to its production, particularly since there appears to be no pressing U.S. requirement. We are also concerned about the growing cost of the program and, in particular, the cost to acquire and install the engine in the DDG-51. While the U.S. Navy has entered into cooperative agreements with the United Kingdom and France, it is still funding about 93 percent of the engine's estimated \$415 million development cost. Program restructuring, schedule slippage, and expected cost increases will add to that amount. The decision of the program office to advance the engine's schedule by concurrently conducting advanced development along with full-scale development 1-1/2 years prior to testing the engine and recuperator together and then, after the recuperator failure, to initiate an aggressive recuperator recovery plan heightens our concern about program management. We also are concerned that the Navy may significantly reduce the testing of the ICR engine in an attempt to offset program cost growth and the additional cost caused by the recuperator failure. We also continue to question the Navy's proposal to put the engine on the DDG-51 and its decision to manage the program as a DDG-51 preplanned product improvement.

DOD's comments are presented in appendix I. In addition, DOD provided, for our consideration, several factual and technical corrections related to the report. In response, we have made changes to the report where appropriate.

Scope and Methodology

To obtain information for this report, we reviewed various program research and development documents, including the recuperator recovery plan, early concept and feasibility design studies, test plans and schedules, various development contracts and other program documents. We interviewed officials in the offices of the Under Secretary of Defense (Comptroller/Chief Financial Officer), DOD's Director of Operational Test and Evaluation, Assistant Secretary of the Navy (Research, Development and Acquisition), Navy's Operational Test and Evaluation Force, and the Naval Sea Systems Command's Advanced Surface Machinery Program,

Engineering Division, Land Based Engineering Site, and Naval Surface Warfare Center. We also reviewed various DDG-51 program documents and interviewed officials in the offices of the Under Secretary of Defense (Acquisition and Technology) and the DDG-51 Program Office. We also discussed our report with the Naval Audit Service.

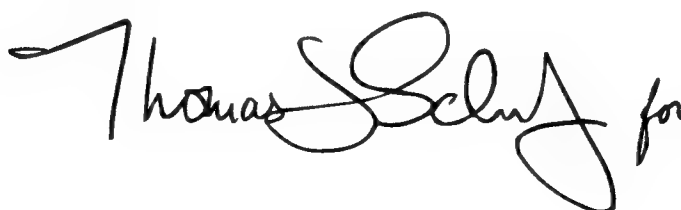
To assess and analyze the risks associated with the recuperator recovery plan, we attended two ICR bimonthly technical conferences where program officials and contractors discussed technical and testing issues, including engine performance, testing problems, and the recuperator recovery program. We compared information obtained at these conferences with various program and technical documents.

We conducted our review from May 1995 to May 1996 in accordance with generally accepted government auditing standards.

We are also sending copies of this report to the Chairmen and Ranking Minority Members, House Committees on National Security and on Government Reform and Oversight, Senate Committees on Armed Services and on Governmental Affairs, and Senate and House Committees on Appropriations; the Director of the Office of Management and Budget; and the Secretaries of Defense and the Navy. We will also provide copies to others upon request.

This report was prepared under the direction of Thomas J. Schulz, Associate Director, Defense Acquisition Issues. Please contact him or me on (202) 512-4841 if you or your staff have any questions concerning this report. The major contributors to this report are listed in appendix II.

Sincerely yours,

A handwritten signature in black ink that reads "Thomas Schulz for". The signature is stylized with a large, flowing "T" and "S".

Louis J. Rodrigues
Director, Defense Acquisitions
Issues

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Abbreviations

ICR	intercooled recuperated
DOD	Department of Defense

Comments From the Department of Defense



OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000



APR 17 1996

Mr. Thomas J. Schulz
Associate Director, Defense Acquisition
Issues
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Schulz:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "NAVY SHIP PROPULSION: Viability of New Engine Program in Question," March 25, 1996, (GAO Code 707113), OSD Case 1118. The Department nonconcurs with the report.

The report requires several factual and technical corrections which were provided separately. DoD supports the ICR Program development. The ICR has the potential to provide significant benefit to the Navy.

The detailed DoD comments to the report recommendations are provided in the enclosure. The Department appreciates the opportunity to comment on the draft report.

Sincerely,

A handwritten signature in cursive script, reading "George R. Schneiter".

George R. Schneiter
Director
Strategic and Tactical Systems

Enclosure



GAO DRAFT REPORT
(GAO CODE 707113) OSD CASE 1118

"NAVY SHIP PROPULSION: Viability of New Engine Program in Question"
March 25, 1996

DOD RESPONSE TO GAO RECOMMENDATIONS

RECOMMENDATION 1: The Secretary of Defense reassess the Navy's continuing need for the new engine.

DOD RESPONSE: Nonconcur. The Navy has closely monitored the expected return on investment of the ICR engine. In 1994, the Navy tasked the Center for Naval Analyses (CNA) to do an analysis of the ICR program. This study supported continuing ICR development and was forwarded to Congress in December 1994 by Secretary Dalton. The Secretary was satisfied with the CNA assessment and does not need to reevaluate the program at this time. Additionally, the Secretary of Defense views the international cooperative program as beneficial to interoperability, a means to stretch declining defense budgets and preserve local defense industrial capabilities.

RECOMMENDATION 2a: If it is determined that the program should continue, the Secretary of Defense should direct the Secretary of the Navy to not use the engine in the DDG 51 destroyer.

DOD RESPONSE: Nonconcur. The Navy has been authorized to make a decision regarding the DDG 51 in 1997. Currently, the ICR is expected to provide military advantages to the DDG 51 such as increased range and time on station. These changes are considered desirable and formed the basis for a USD(A&T) decision to approve the P³I plan for the DDG 51 Flight IIA program in February 1994.

The GAO recommendation is based on concerns that the ICR engine is too heavy and too large to be used on the DDG 51. DDG 51 installation studies done by Ingalls Shipbuilding Division determined that the increased engine weight can easily be accommodated because the fuel efficiency of ICR reduces DDG 51 fuel requirements resulting in a net weight savings. The Ingalls DDG 51 study determined that the seawater heat exchanger module could be located in the space previously used for the high pressure air compressor. NAVSEA studies in other classes of future ships including amphibious, logistics and combatant ships show that volumetric changes can be easily accommodated.

RECOMMENDATION 2b: If it is determined that the program should continue, the Secretary of Defense should determine total program costs for developing and acquiring the engine relative to the Navy's requirements for future surface combatant ships, including costs for U.S. test facilities and/or pilot ship engine testing.

Enclosure (1)

DOD RESPONSE: Partially Concur. Total program costs have already been estimated. CNA found that the ICR begins to pay off after approximately 14 ships are delivered and breaks even after 79 ships are delivered, approximately 2020. By the year 2040, CNA projects savings in current year dollars of over \$400M after the investment costs are recovered. CNA estimated these savings using a conservative estimate of annual savings of only \$650,000 per ship per year.

It must be noted that the CNA study is purely an economic analysis. The Department's decision is based upon a more complex set of factors. These include critical operational benefits such as increased range and endurance, reduced signatures, and the ability to comply with projected environmental regulations.

RECOMMENDATION 2c: If it is determined that the program should continue, the Secretary of Defense should prepare a test plan and schedule for the engine that provides sufficient assurance it can transition from development to production and be realistically available for use in the Horizon or another future ship.

DOD RESPONSE: Partially Concur. The Navy will address requirements for additional testing in conjunction with the DDG 51 Propulsion decision in 1997. At that time, if the decision were made to use the ICR engine on DDG 51, test planning and scheduling would be incorporated into the DDG 51 Test and Evaluation Master Plan (TEMP). For future ship developments, ICR test planning will be incorporated into the TEMPs for those programs. The Horizon program as a tripartite effort between the United Kingdom, France and Italy. Those countries will develop their own test plans in accordance with their acquisition directives. The United States has no cognizance over the Horizon program.

Enclosure (1)

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